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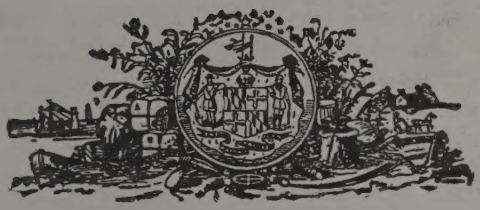
Fruit-Rotting Sclerotinias
III. Longevity of Buried Brown-Rot Mummies

By WALTER N. EZEKIEL



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Bulletin No. 284 October, 1926

FRUIT-ROTTING SCLEROTINIAS
III. LONGEVITY OF BURIED BROWN-ROT MUMMIES

By WALTER N. EZEKIEL

SUMMARY

The value of the practice of plowing mummies of brown-rot peaches (*Sclerotinia americana* (Wormald) Norton and Ezekiel) [1] under ground, long recommended as an auxiliary control measure against brown-rot, has been questioned on the basis of observations showing that plum sclerotia could survive for as long as ten years. The experiments discussed in the present paper prove that plowing brown-rot mummies under does prevent the growth of apothecia.

In preliminary experiments it was found that burying mummies more than an inch below the surface of the soil prevented the growth of apothecia, but that no permanent effect was produced on the mummies, unless they actually disintegrated before being again brought to the surface. Plum mummies seemed more durable and disintegrated less rapidly than the peach mummies used.

Extensive experiments, in which peach mummies were distributed in duplicate series at four different depths in both wet clay and dry sand soils, showed that in both soils buried mummies disintegrated rapidly while mummies on the surface were well preserved and produced apothecia. Even old, weathered mummies disintegrated enough when buried less than ten months to prevent the production of apothecia.

It is accordingly recommended as an auxiliary control measure that peach brown-rot mummies lying on the ground be plowed under after rotten fruits are picked off the trees in fall or before the early pink-bud stage of the blossoms in spring.

[1] This is the brown-rot organism common in this country and formerly confused with *S. cinerea* (10). The name *S. fructicola* (Winter) Rehm is used in some current literature to refer to the same species.

INTRODUCTION

For more than twenty years, beginning with almost the first scientific studies of the common brown-rot disease of stone fruits in this country, one of the most frequent recommendations for auxiliary control measures has been to "plow under the old brown-rot mummies lying on the ground." At first this was with the idea of preventing infection by conidia (*15*, *12*). More recently, since Norton (*9*) discovered that the apothecial stage was produced from these old mummies, burying the mummies has been advised on the hypothesis that this would prevent the growth of the apothecia; and observations by Dandeno (*3*) and investigations by the writer (*4*) have proved the truth of this hypothesis.

The value of this auxiliary method of control has, however, been questioned by Stevens (*16*) and Howitt (*8*) on the basis of some observations recorded by Pollock (*13*), who found that plum mummies ten years old were still capable of producing apothecia. Pollock thought it was "obvious that if the ground should again be plowed within ten years the mummies [previously plowed under] that were brought near the surface, say within one or two inches, would still be able to produce their apothecia"; and Stevens states: "In the light of these observations attesting to the long life of the sclerotia, the plowing under of diseased fruits, heretofore advised, cannot be regarded as a good practice."

Now, while it was thus noted that plum sclerotia were able to survive for as long as ten years, observations have shown that in fact apothecia and even old sclerotia are rare or entirely absent in peach orchards where the mummies are plowed under regularly, while they may be abundant in nearby unplowed orchards. Similar observations have been recorded by Brooks and Fisher (*2*) in prune and cherry orchards of the Pacific Northwest.

Preliminary Experiments. In 1920, about 2,800 plums and 1,000 peaches were inoculated with *Sclerotinia americana*, using as inoculum conidia from brown-rot fruits gathered in the University orchards. After rotting, the mummies were used, August 20, 1920, in an extensive series of experiments having to do with the effect of environmental conditions on the growth of apothecia and previously reported (*4*, *11*) from that viewpoint.

About one-third of the mummies were used in the laboratory at different depths in the soil, in boxes kept at various temperatures. As these were examined from time to time, it was noted that in general the more deeply buried mummies disintegrated rapidly, except in series in which the soil was maintained completely saturated, in which case mummies on the surface rotted first and the buried ones were the better preserved.

The other two-thirds of the mummies were placed outside, under natural conditions, at five different depths in the soil. The follow-

Fig. 1.—Apothecia of *Sclerotinia americana*, the fungus that causes the common brown-rot of peaches, plums and cherries in the United States. These mushroom-like reproductive bodies arise in spring from the old mummies lying on the ground, and discharge into the air, just at blooming time, innumerable spores which infect the blossoms and cause blossom-blight. Another kind of spore, produced on the blighted blossoms, then spreads in the wind to cause the familiar brown-rot (x $1\frac{1}{3}$).

ing spring, apothecia developed only from mummies buried one inch or less deep (mostly from those only half buried in the soil) and none from the lot that was buried two inches deep. On April 28, 1921, some of the mummies at each depth were dug up, examined, and placed back in the ground half buried in the soil. The following spring (1922) apothecia developed abundantly from all these mummies, including those previously buried two inches deep. The rest of these mummies under natural conditions were left in the soil until November 24, 1922, a little more than two years after the beginning of the experiment. By this time many of the mummies had been shifted from their original depth in the soil by rain storms and comparative results as to the condition of mummies in relation to depth could not be obtained. It was found, however, that the peach mummies were generally rotted away so that only the bare stones were left, while many of the plum mummies were still in perfect condition.

In another experiment, peach mummies from which apothecia had already started to grow were collected in local orchards and placed (March 12, 1921) at different depths in the soil in the greenhouse. For three weeks apothecia developed from mummies on the surface and those partly buried, but not from buried ones. Isolations from

these apothecia were identified as *Sclerotinia americana* var. I, III and IV (*6*). On April 2 these mummies were dug up and all found to be in good condition. The surface lots, which had borne apothecia, and the buried ones which had not, were placed in separated lots under natural conditions outside. Apothecia developed abundantly in 1922 and 1923 from both lots.

Discussion of Preliminary Experiments. In the experiments summarized above the following was observed: (1) Burying mummies more than one inch deep inhibited the growth of apothecia, even if growth had already begun when the mummies were buried. (2) Peach mummies buried for three weeks in a moist soil, at a depth preventing the growth of apothecia, were not appreciably decayed when removed; and under favorable conditions produced apothecia in subsequent years. (3) Plum and peach mummies buried for eight months were also able to produce apothecia after being placed under suitable conditions (the notes did not state whether these apothecia arose from peach or plum mummies, but it was recorded that the peaches were much the more disintegrated). (4) In other experiments also, it was noted that under the same conditions peach mummies rotted faster than plum mummies (The plums here were all of the Marianna variety.)

This then demonstrated that there is no permanently injurious effect to the mummies directly from burying *per se*. The production of apothecia is inhibited during the time sclerotia are buried without causing a profound enough change within the sclerotia to affect the development of apothecia later if the mummies are brought under conditions permitting apothecial growth. Thus it seems that though apothecia will not grow from mummies previously plowed under while they are buried, any final effect on the production of apothecia after the mummies are plowed up again must be from the actual destruction of the mummies while they are buried.

It was accordingly of considerable interest to find out more precisely whether buried peach mummies disintegrated much faster than those left on the surface. The aim of the experiments reported below has been to obtain evidence bearing directly on this point and to furnish a definite answer to the question of whether the plowing under of peach brown-rot mummies is advisable.

METHODS

In one series of experiments peaches of three different varieties were inoculated with conidia of *Sclerotinia americana*, allowed to rot, and then distributed in lots of equal composition at different depths in two soil types, a dry sand and a wet clay. The second series included lots made up from the leathery and well-hardened sclerotia still surviving in the surface lots at the end of the first series of

experiments. Observations were made on the preservation of the mummies, and the production of apothecia, both *in situ* and after the lots were dug up and placed on the surface of the soil under conditions suitable for the production of apothecia.

The mummies were buried in "trays," two feet square and one foot high, of galvanized 1-3 inch wire mesh hardware cloth, with covers of the same material and metal labels wired in place. Trays, labels and wire fastenings were all carefully paraffined. In each series half of the lots were placed in a stiff, very poorly drained, level clay soil (Susquehanna clay) close to the laboratory. The others were put in a light, well drained bank sand (Sassafras loamy sand). This sand was almost perfectly drained, as it was located in a pit excavated for the purpose on the side of a steep bank. The soil used inside the trays with the mummies was sieved to facilitate removing it when mummies were examined. In each tray, the mummies were separated by at least two inches of soil in every direction from even the paraffined metal surfaces. Depths given are for the mummies rather than the trays which protected them, and are measured from the tops of the mummies to the surface of the soil, except that mummies on the surface were placed free on the smoothed surface of the soil.

The soil was undisturbed from the time of burial until observations were made, except that weeds were removed each spring throughout the investigation to facilitate observations on the growth of apothecia. In digging up the buried lots extreme care was always taken to avoid mechanical injury to the mummies. The soil was separated by hand from the mummies as lumps of earth were removed from the tray with a trowel. After examination the mummies of each lot were then replaced in the trays, each mummy partially covered with the surface soil, for which the earth previously separated from immediately around them was used. The purpose of thus transferring not only the mummies themselves but also the earth surrounding them to the surface was to supply depth conditions permitting the development of apothecia to bits of sclerotia too small to be noticed as well as to the large ones. The effect was similar to that obtained by plowing up buried mummies, except that the shearing pressure incident to plowing, and undoubtedly destructive to the mummies, was omitted; and that all mummies of an appreciable size were placed at the optimum depth for the production of apothecia.

EXPERIMENTS WITH NEW MUMMIES

To secure material of known history, but of a heterogeneous nature so as to be more nearly comparable to mummies as found in orchards, sound peaches of three varieties were inoculated, as they ripened at different times, with conidia directly from rotted fruits collected in the University orchards. Two and a half bushels of

Greensboro peaches were inoculated on July 8, 1922; a similar quantity of Elberta peaches on August 17; and two and three-fourths bushels of Late Crawford peaches on August 30. The rotted peaches used as sources of inoculum all showed the typical symptoms of the common brown-rot, caused by *Sclerotinia americana*. No isolations were made from them, but previous collections in the same orchard had demonstrated the presence of a number of varieties (*6*) of *S. americana*, and single-spore strains subsequently isolated from apothecia growing from the mummies during the investigation were identified as *S. americana* var. III. The inoculated fruits were spread out to rot in the wire mesh trays, stacked in a half-shaded mushroom cellar. The mean temperatures for the first two weeks were 26.5°, 24.2°, and 25°C., respectively for the three lots, varying daily from about 20° to 30°C.

Seventeen composite lots were prepared from these mummies, each containing 100 mummies of which 45 were Greensboros, 20 Elbertas, and 35 Late Crawfords. Of these, sixteen lots were distributed, as shown in Table I, on the surface and at three, eight, and eighteen inches depth in the soil, in duplicate series in each soil type. Lot 17 was suspended in the air in one of the trays, to simulate naturally infected mummies hanging to the trees.

The mummies were placed in the various positions indicated in Table I, in the fall of 1922. No apothecia at all developed in the following spring. One lot at each depth was dug up, examined, and placed on the surface of the soil after about fourteen months, and the other after about twenty months, as detailed in Table I.

Condition of Mummies after Fourteen Months. Detailed notes were taken on the state of preservation of the mummies when they were dug up. In the sixth column of Table I the percentage of preservation is given, as estimated from observations on the mummies in comparison with the concept of the type of mummy capable of producing apothecia as formed by the writer in previous experience with Sclerotinia apothecia (*4, 5, 11*) and as confirmed from time to time by Dr. J. B. S. Norton. The percent estimate in the table applies to the number of individual mummies that appeared still able to produce apothecia, not necessarily to the amount of original mummy material that was left. That is, a dark, tough, leathery mummy, the sort present in abundance in lot 1 on December 20, 1923, was counted equally preserved whether it was of a size that would produce fifty apothecia or only one. In fact, while about 95 of the original 100 mummies of lot 1 were still apparently capable of producing apothecia, very few of these mummies were still entirely intact. Most of them had rotted on the side in contact with the ground until from a quarter to a half of the mummy was disintegrated and the bare peach stone touched the ground. In this lot, only one mummy had rotted away so that only the stone was left.

TABLE I.—SUMMARY OF EXPERIMENTS WITH PEACH MUMMIES FROM FRUITS RECENTLY INOCULATED WITH SCLEROTINIA AMERICANA CONIDIA

Lot	Soil type	Depth in soil	Date placed at original depth	Date dug up and placed on surface	Approximate preservation of mummies when dug	Apothecia produced, notes April 23, 1924
					percent	
1	Sand	Surface	Oct. 26, 1922	Dec. 20, 1923	95	+++
2	do.	3 in.	do.	do.	0	–
3	do.	8 in.	do.	do.	0	–
4	do.	18 in.	do.	do.	0	–
5	do.	Surface	do.	June 17, 1924	98	–
6	do.	3 in.	do.	do.	0	–
7	do.	8 in.	do.	do.	0	–
8	do.	18 in.	do.	do.	0	–
9	Clay	Surface	Oct. 19, 1922	Dec. 21, 1923	95	+++
10	do.	3 in.	do.	do.	0	–
11	do.	8 in.	do.	Dec. 23, 1923	0	–
12	do.	18 in.	do.	do.	1	–
13	do.	Surface	do.	June 18, 1924	85	++
14	do.	3 in.	do.	do.	0	–
15	do.	8 in.	do.	do.	0	–
16	do.	18 in.	do.	do.	0	–
17	Suspended in the air.				90 (June 19, 1924)	–

By contrast, not a single well preserved mummy was found in the buried lots harvested at this time, lots 2, 3, and 4. The mummies though frequently still to be recognized by their shape, were almost completely softened and nearly perfectly disintegrated, and could be separated from the sand only with difficulty. The following is quoted from field notes made at the time: "Instead of mummies being leathery and tough, they are of an even earthy consistency, almost continuous with the surrounding soil, with a general appearance as the soil was removed of being merely slightly more homogeneous, yet quite crumbly, black regions in the yellow sand." Far from looking like sclerotia at all, the material removed was rather a well-decayed humus. The best preserved mummies of these buried lots were some in lot 4 that showed some traces of an indefinite, leafy structure; even these were quite friable and could not have been confused with mummies containing sclerotia capable of producing apothecia.

In the set of lots harvested December 21 and December 23 from the clay series, a similar relation was shown between the depth of the mummies in the soil and their state of preservation. Almost all the mummies of lot 9, on the surface of the soil, were leathery,

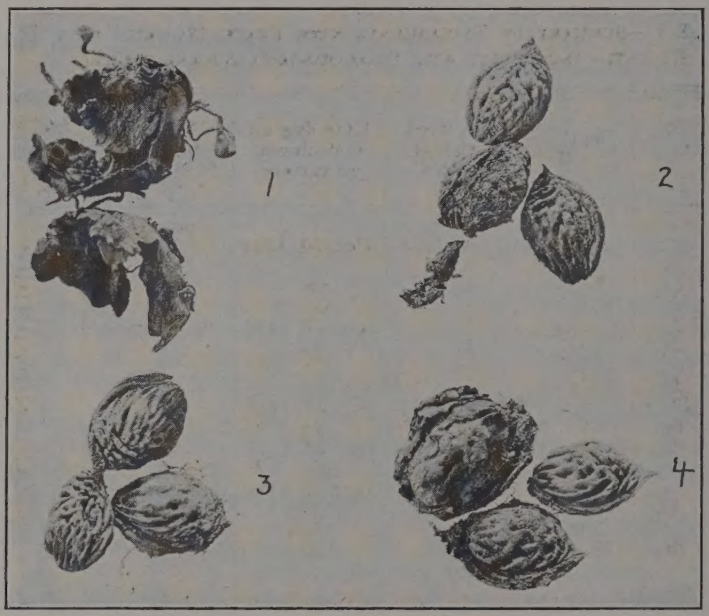

Fig. 2.—Mummies representative of lots 1 to 4, photographed April 23, 1924. Apothecia were produced only in lot 1, on the surface of the sand. The peach stones have been removed from the mummies of this lot to show the apothecia.

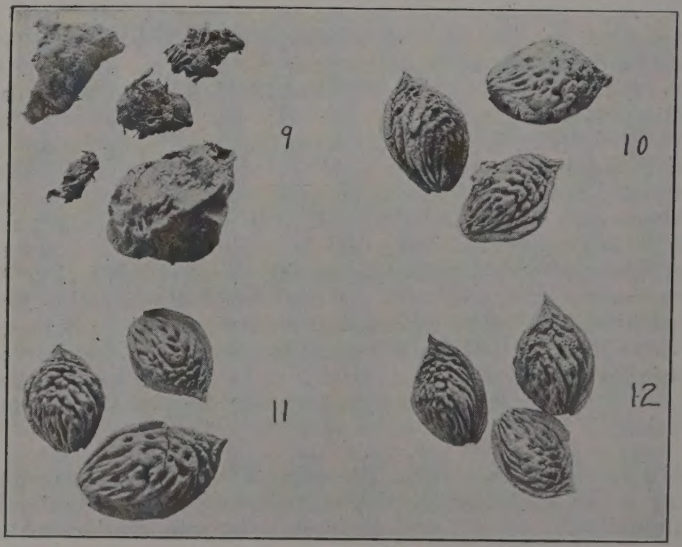

Fig. 3.—Mummies representative of lots in the clay soil, photographed April 23, 1924. Apothecia developed only in the surface lot, 9.

black specimens, almost optimum for the production of apothecia. As before, mummies of the buried lots were nearly completely disintegrated, the best preserved ones showing only a fleshy or fibrous structure while most of them were recognizable only as dark stained regions in the soil surrounding the stones.

Development of Apothecia. Observations as early as March 25, 1924, showed the presence in the different surface lots of many mummies from which apothecial primordia (Stage II of *11*, p. 18) were already growing. On April 12, immature apothecia were recorded in lots 1, 9, and 13. The condition of the mummies at this time was of interest. The mummies of the buried lots that had been dug up the preceding December (lots 2, 3, 4, 10, 11, and 12) had now completely disintegrated so that generally only the clean stones were left, though a few still had crumbly or fibrous black masses of material clinging to them. All the surface lots—1, 5, 9, and 13—were still in excellent condition.

By April 23 the apothecia observed before were maturing. In lot 1 there were 13 mature and 64 immature apothecia; in lot 9, 1 mature and 127 immature; and in lot 13, 5 mature and 17 immature ones. Most of the apothecia that were still immature at this time probably did not develop further. No apothecia could be found in any of the other lots. In Figs. 2 and 3 some of the apothecia found in these surface lots are shown with the solid mummies on which they were produced, as compared to the bare peach stones that were all that was left of the lots that had previously been buried in the ground.

Condition of Mummies after Twenty Months. The rest of the mummies were dug up and examined on June 17 and 18, 1924. In both the sand and clay soils the surface lots (5 and 13) were well preserved; and many tough, black, leathery mummies were found, still in excellent condition. On the other hand, the buried mummies (lots 6, 7, and 8 in sand; 14, 15, and 16 in clay) were without exception completely disintegrated. They showed no traces of definite structure, the dark, crumbly masses merging imperceptibly into the surrounding soil.

The mummies in lot 17, which was suspended in the air in its wire mesh tray throughout the experiment, were in good shape and showed the deep black color and leathery texture typical of old mummies well filled with sclerotia. About 25 per cent of them were still intact, in the original forms; about 10 per cent were completely destroyed so that only the bare stones remained; and the rest were partly rotted away but still showed sufficient sclerotium to justify their inclusion as mummies capable of developing apothecia under suitable conditions.

EXPERIMENTS WITH OLD, HARDENED MUMMIES

At the end of the above series of experiments, of the mummies used as material, those buried in the soil were now completely disintegrated while in the surface lots and in lot 17 many leathery, black mummies were left. These latter mummies, the sort to be found on the ground in old orchards, were much tougher and apparently more rot-resisting than new and unweathered mummies. The question arose whether these well hardened mummies also could be destroyed by burying them in the soil, and the following series of experiments was accordingly performed.

The mummies of lots 1, 5, 9, 13 and 17 were taken up and each of these old lots divided into six portions containing approximately the same amount and type of mummy material. These portions were then combined to make six new lots, each a composite of this old, well mummified material with its differing history. On June 20, 1924, the lots were distributed as indicated in Table II to three different depths (on the surface, buried three inches and buried eight inches) in the sand and clay soils.

On March 10 the buried lots were dug up and carefully examined. It was found that while these mummies had not disintegrated completely into the soil as had been the case with buried mummies in the other series, they had become much softer and more friable than when they were buried. The mummies in these lots (19, 20, 22, 23) generally still retained their form but had rotted to such an extent as to break up with a slight shearing pressure. A very few of the mummies were still slightly fleshy or fibrous, especially in lot 23 which was best preserved of the buried lots. However, even these had deteriorated to such an extent as probably to be unable to produce apothecia, and they would doubtless have been completely broken up into the soil by such an operation as plowing or harrowing.

TABLE II.—SUMMARY OF EXPERIMENTS WITH OLD BROWN-ROT MUMMIES, STARTED JUNE 20, 1924

Lot	Soil type	Depth in soil	Approximate preservation of mummies, March 10, 1925	Apothecia produced, notes April 11, 1925
			percent	
18	sand	surface	100	—
19	do.	3 in.	0	—
20	do.	8 in.	0	—
21	clay	surface	95	++
22	do.	3 in.	0	—
23	do.	8 in.	0	—

On the other hand, in the surface lots, 18 and 21, the mummies were in almost as good condition as at the beginning of the experiment. Most of them were still hard and leathery and appeared still capable of apothecial production. That this estimate was correct was shown by the discovery of between 50 and 75 apothecial primordia on two large mummies which had been partly pushed into the moist clay soil, in lot 21. Periodic search during the spring, on March 19 and 26 and April 11 and 27, failed to disclose the presence of apothecia in any of the other lots.

DISCUSSION

The experiments described have furnished unequivocal evidence in regard to the point at hand in the case of peach mummies. Buried peach brown-rot mummies, whether new ones of the current season or old, tough, leathery ones of two summers previous, consistently disintegrated rapidly under conditions at all comparable to those to be found in orchards. The preliminary experiments in boxes had shown that in a completely saturated soil rotting was prevented, but this was far from the case even in the very wet, undrained, Susquehanna clay soil used later. Under natural conditions an agricultural soil apparently can scarcely be wet enough to prevent the disintegration of Sclerotinia mummies.

It has been possible to confirm the validity of the estimates of the preservation of mummies throughout these experiments by the production of apothecia. Except in the preliminary experiments in which mummies were buried for short times, apothecia developed only in lots that had never been buried.

When surface lots of mummies failed to produce apothecia it was plainly caused by prevailing moisture conditions. Thus lot 5 (Table I) did not produce apothecia in April, 1924, along with lots 1, 9 and 13. The explanation is that lot 5, a surface lot on dry sandy soil, was never moist enough to allow apothecial growth. Lot 1, though also on the surface of the sand, had been examined the previous December, and as usual had all its mummies placed half-buried in the soil, after examination, to facilitate the growth of apothecia as a check on the results of the observations. The presence of apothecia at this time in lot 13 is attributable to the fact that the clay soil was so wet that apothecia could grow even from mummies merely resting on its surface. Similarly, apothecia appeared in lot 21 (Table II) from mummies on the moist clay soil, but not from lot 18 on the sand.

These results emphasize again the previous conclusion (*11*, p. 16) that the moisture supply is usually the limiting factor in the growth of apothecia from such mummies as are at a suitable depth for apothecial development. Plowing or harrowing the ground in

spring before apothecia are mature will thus aid in preventing their growth, by loosening them from contact with the ground water supply and also by disturbing such debris on the ground as might keep developing apothecia moist. Clean culture and other orchard operations that result in disturbing the ground before blossoming time therefore not only prevent the production of apothecia and hasten the disintegration of such mummies as are buried by this treatment, but also tend to stop the growth of apothecia even from mummies that are still at a suitable depth in the soil.

These conclusions are of course strictly applicable only to such material as that with which the experiments were performed. As noted above, the plum mummies used in the preliminary experiments were apparently more durable than the peach mummies, and were not disintegrated by eight months burying. However, whether or not plum mummies can be completely destroyed by burying them for a year, there can be little doubt but that clean culture will tend to reduce the numbers of apothecia produced under plum trees as well as under peaches.

The discussion above is all concerned with the common brown-rot organism, *Sclerotinia americana,* which produces apothecia abundantly under favorable conditions. With the Pacific Coast blossom-blight diseases (*1*, *14*) shown to be caused by *Sclerotinia cinerea* (*7*) the case is different. This species apparently produces apothecia only rarely, and seems to be perpetuated in orchards chiefly by conidia produced on diseased twigs and fruits clinging to the trees, so that the destruction of mummies under the trees would be of little or no value in lessening infection.

Recommendations. It is to be remembered that auxiliary methods of controlling brown-rot, such as reducing initial infection in spring from apothecia by burying mummies in the ground, can hardly be expected to obviate the necessity of carrying out the usual spray program. Such methods will also be of less value, even in lowering infection, if old brown-rot mummies from previous seasons are allowed to stay on the trees. These mummies will produce conidia that blow or wash to the fruit below and around them. All brown-rot mummies should be removed from the trees, even if they are only dropped to the ground between the trees. Here they can be disposed of, along with the mummies that fall to the ground naturally, by methods discussed in an earlier bulletin (*11*) [1] or by plowing them under as discussed in the present publication.

The experiments here were performed in soils of respectively extreme enough high and low moisture content to make biological activity less than in any soils in which peach trees would be grown. In spite of this, buried mummies disintegrated almost completely

[1] Persons interested may obtain copies of this bulletin by writing to the Experiment Staton for Bulletn 256.

in fourteen months and even old, weathered mummies disintegrated enough in less than ten months to prevent the growth of apothecia from them. Finally, apothecia developed from mummies that had been on the surface, but not from the considerably greater number that had been buried. We may then conclude that orchard operations that will result in burying peach mummies, even though they are plowed up again in a year, will prevent the production of apothecia.

The procedure to be recommended in particular orchards will necessarily vary with the climate, local conditions, the soil, topography of the orchard, cover cropping systems followed, etc. To keep down the production of apothecia it will probably be sufficient to plow under the mummies lying on the surface of the ground at any time after all rotten fruits are picked off the trees in late summer and before the early pink-bud stage of the blossoms in spring, when the first infection by ascospores to be expected.

Probably the best procedure would be to plow the mummies under in fall, and then cultivate or otherwise loosen the surface soil in spring, at least once before the pink-bud stage. Except in very moist soil, recently plowed land is not likely to offer favorable enough moisture conditions for the development of apothecia, should there be any mummies present that escaped the first plowing. In any case, care should be taken to work the ground close to the trees so that large furrows will not be left to furnish exceptionally favorable situations for the growth of apothecia from such mummies as lodge in them.

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